Communication Theory - Report

Assignment – 2: Coding questions

Soham Vaishnav | 2022112002

Q1:

(25 marks) In this question, you will implement DSB-SC modulation and then perform demodulation, using few different methods.
You will use the following signals:
Message signal:

$$m(t) = \Delta(t+1) - \Delta(t-1) \quad (1)$$

where $\Delta(t) = (1 - |t|)I_{[-1,1]}(t)$ is the triangle function.
Carrier signal:

$$c(t) = A_c cos(2\pi f_c t) \quad (2)$$

with carrier amplitude $A_c = 1$ and frequency $f_c = 100MHz$.

It is advised to make separate functions for each of the schemes, and one for demodulation, so that they can be called from the main script.

Modulation:

(a) Muliplier modulator: This is the simplest modulation scheme (in code, not in hardware, that's why it is not very commonly used), where an analog multiplier is used to produce an output signal that is proportional to the product of the message and carrier. This is very easy on MATLAB. Just multiply the two signals. This is a good warm-up for the following schemes.

(b) Non-linear modulator: These are much more practical; modulation can be achieved using semi-conductor devices. Refer to the textbook and fig. 4 (also from the textbook :)) for the exact description of the scheme. Note that we want a DSB-SC signal and not a DSB-FC (DSB + carrier) signal.

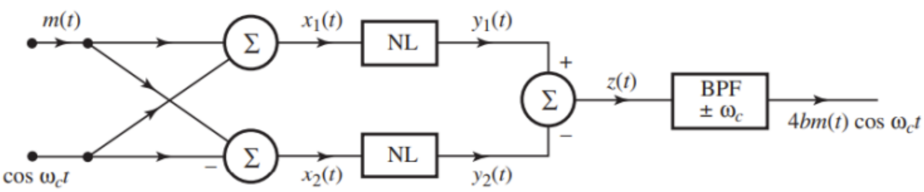


Figure 4: Non-linear modulation scheme

(c) Switching modulation (you did this in AEC, enjoy): Here, we use a periodic square pulse to get a high bandwidth signal, and then use a low pass filter to get only the desired first harmonic AM component. Use a square pulse with no DC offset so that you do not get a message signal component at zero frequency.

Plot the message signal, and the above modulated signals in a 2×2 subplot. For parts (b) and (c) you can perform frequency domain filtering (using in-built functions FFT and IFFT).

Demodulation:
You can use the transmit signals obtained using any of the above schemes for this task (as long as the output is correct). Use a switching demodulator, which involves multiplying by the same square pulse, then using a low pass filter to get the message signal $m(t)$.

Plot in a 1×2 subplot, the original message signal and the demodulated signal.

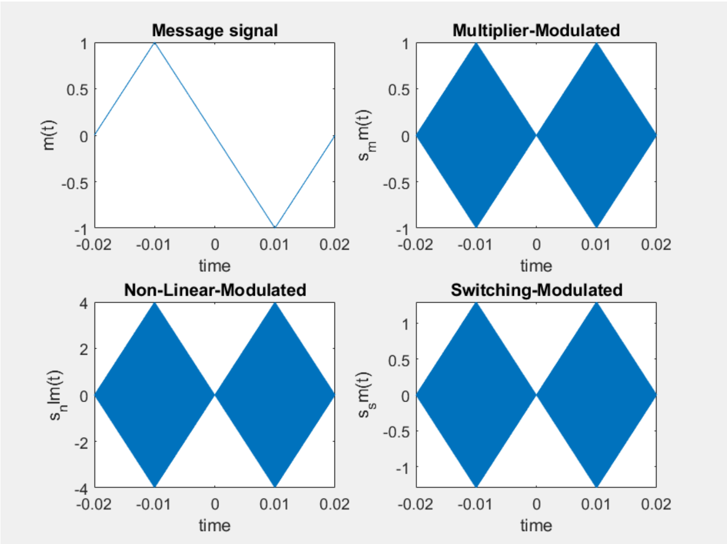
Phase shift effects: One of the main problems with DSB-SC modulation schemes is coherent detection. Here we will analyse the effect of phase shifts in the recieved signals w.r.t. the carrier on demodulation.

Repeat the demodulation performed prior to this, but use a carrier with the following frquency and phase offsets.

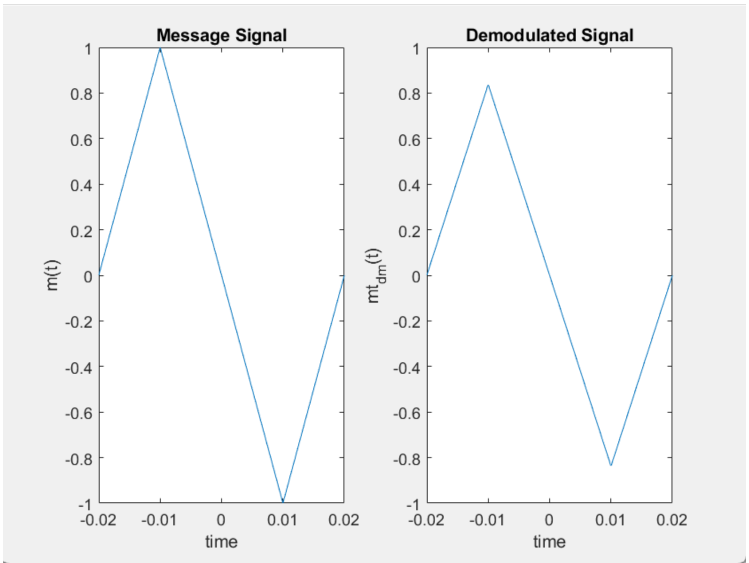
(a) $\Delta f = 0$ and $\Delta\theta = \frac{\pi}{3}$
(b) $\Delta f = 5$Hz and $\Delta\theta = 0$
(c) $\Delta f = 5$Hz and $\Delta\theta = \frac{\pi}{3}$

Frequency spectrum: Now plot the frequency spectrum of the message signal, modulated signal and demodulated signal in a 3×1 plot.

Plots for Q1:

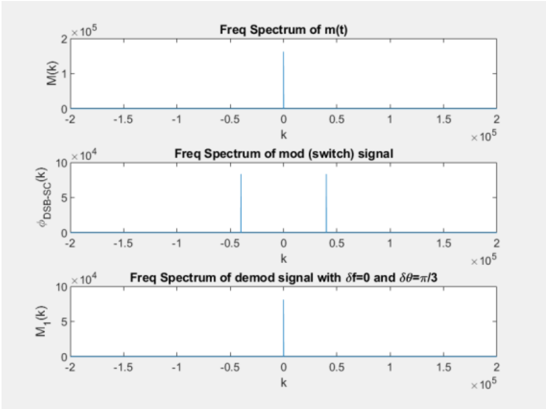


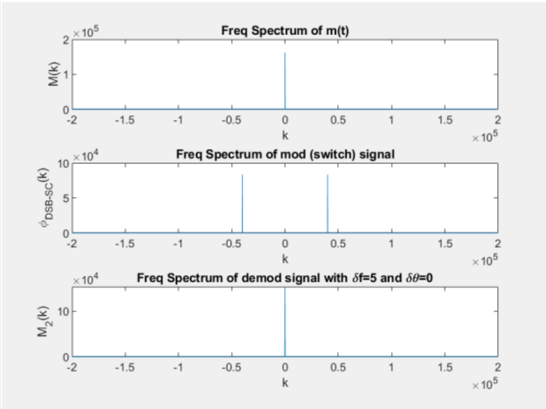
This is the output – modulated signal – using different modulations as mentioned in the title of each plot. Observe, that except for the output from the non-linear modulator, all the other signals have the same amplitudes, however, the waveform for all the signals is same. The reason for different amplitude of the output of the non-linear modulator is due to a factor of 4 which gets multiplied to the signal during non-linearizing of the message signal.

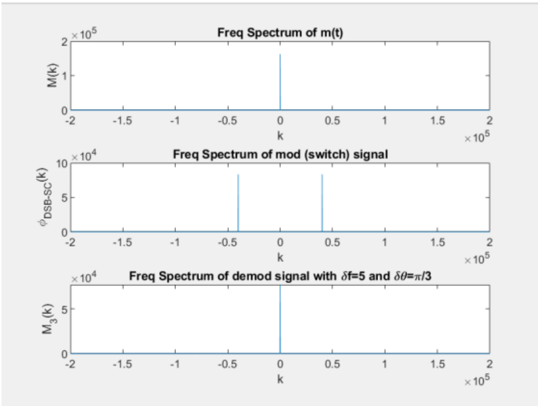


Here, we plot the output – demodulated signal – of the switching-demodulator, which works in the same way as the switching modulator. The only difference being that while demodulating using a switch, we use a LPF at the end to retrieve the message signal, where while modulating we use a BPF to obtain the message signal spectrum at the carrier frequency. Note that the amplitude of the switching modulator is lesser due to the Fourier series coefficients of the switch (rectangular pulse) which get multiplied to the signal while demodulating.

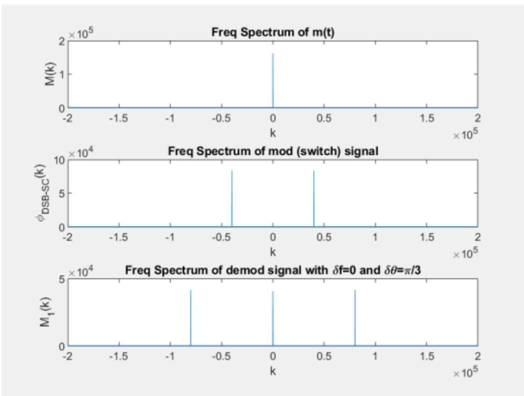
P.T.O

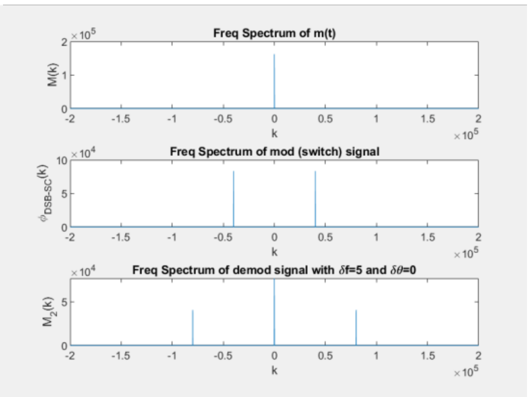


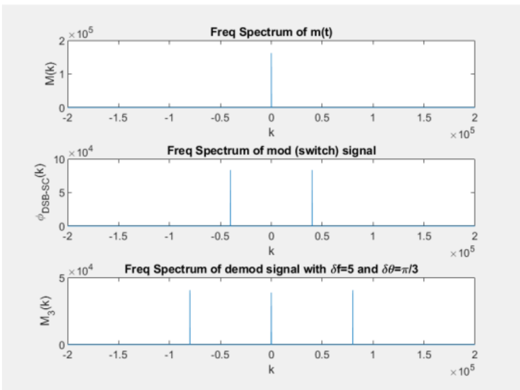




From top-left in clockwise order the plots are for the first, second and third case given in the phase-shifter task, obtained after passing the demodulated signal through the LPF. The following figures in the same order as above show the effect of phase and frequency shift while demodulation.

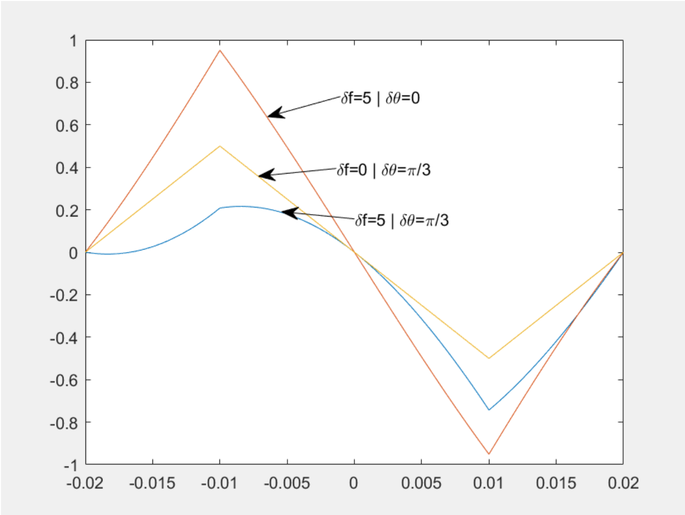






The plots on the next page show the effect of the shifts as observed in time.

P.T.O



Here, in time domain, the effects are quite pronounced!

Q2:

(10 marks) In this task, you will perform DSB-FC modulation, and demodulation using a rectifier detector. Use the same signals as in the previous question. Take $k_f = k_p = 1$

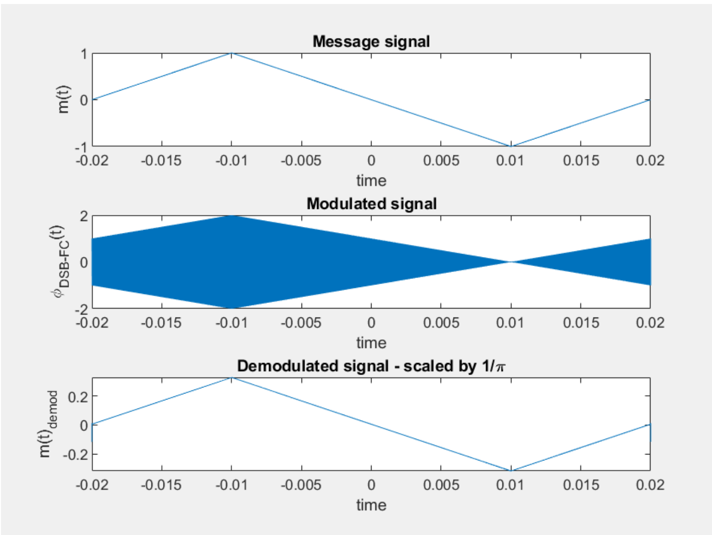
Modulation: Use any of the modulators from the previous question to perform modulation. You can either add the carrier signal after DSB-SC modulation or perform DSB-SC modulation of $A + m(t)$.

Demodulation: Now use a rectifier demodulator to obtain the message signal.

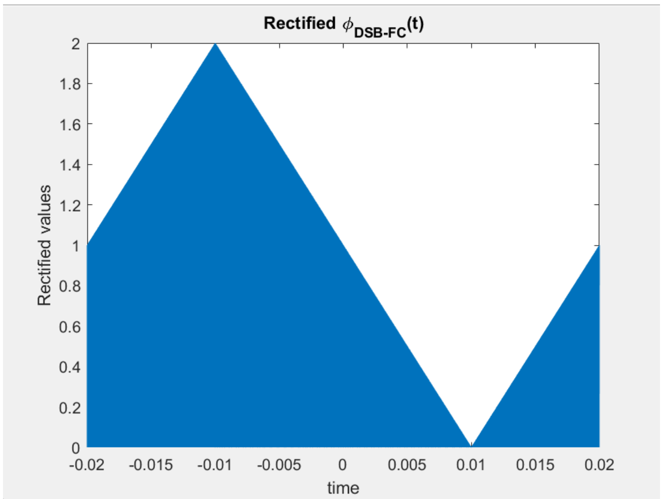
First, produce the rectified version of the signal, then use low pass filtering to get $\frac{A+m(t)}{\pi}$, then finally, block DC to get the scaled message signal $\frac{m(t)}{\pi}$ as the final output (you can use in-built MATLAB functions for low-pass filtering).

We expect two plots:
- A 3×1 plot containing message, modulated and demodulated signals.
- A 2×1 plot containing the frequency spectra of the message and modulated signal.

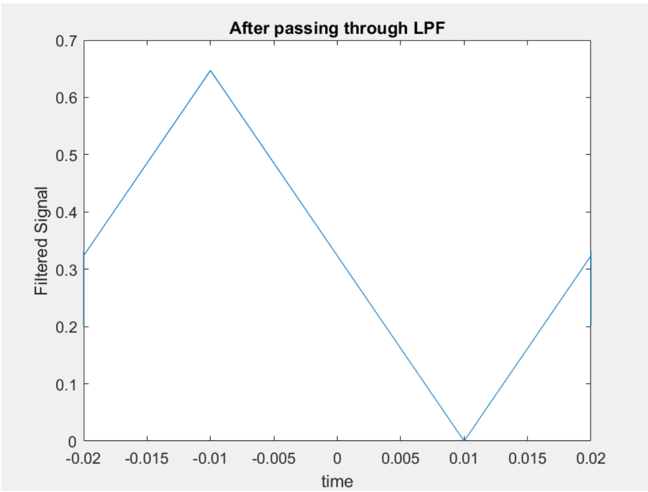
Plots for Q2:



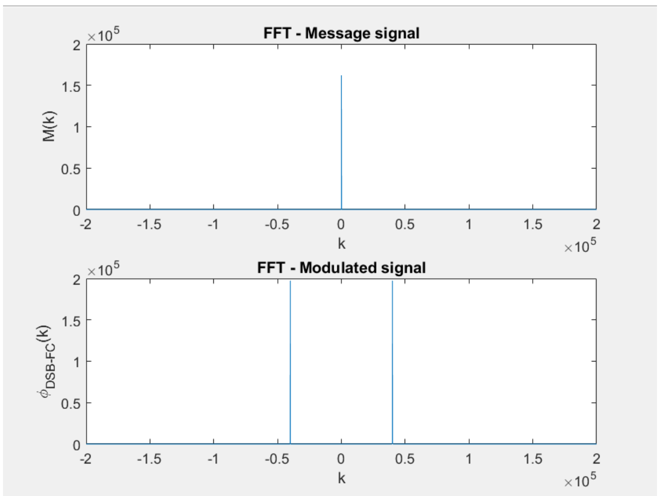
The above plots show the entire modulation-demodulation process of the AM technique. Here, we shift the message signal such that none of it lies below the x-axis (that is, is lesser than 0). With this, while demodulating, we prevent the distortion of the message signal (envelope of the modulated signal). In the final output, the amplitude is less due to a factor of 1/π that gets multiplied to the message signal while demodulation during the process of rectification (where we multiply the modulated signal with the rectangular pulse train – therefore, the factor: FS coefficients of rectangular pulse). Finally, we pass the rectified signal through an LPF to obtain the envelope of the modulated signal. This still contains the DC component (the shift introduced at the beginning) which is then removed.



Rectified Signal



With DC component



The above plots show the FFTs of the message and the modulated signals wherein we can clearly see the effects of AM modulation.

Q3:

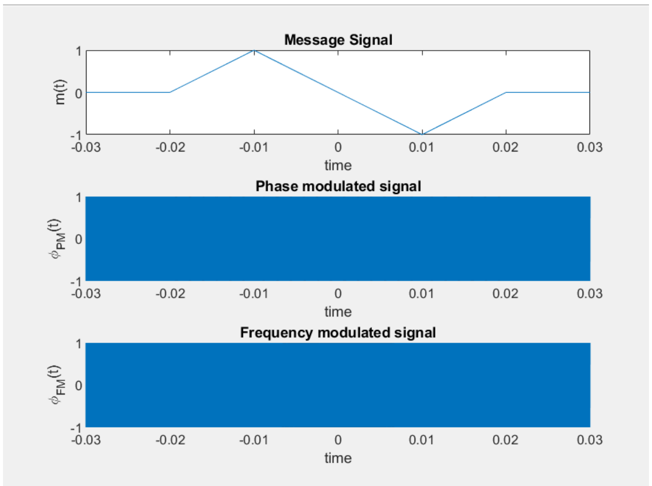
(15 marks) Now you will experiment with FM/PM schemes. Use the same message and carrier signals from the previous questions.

Modulation: Perform frequency modulation and phase modulation and plot the results. A 3×1 plot of the message, FM and PM signals is expected.

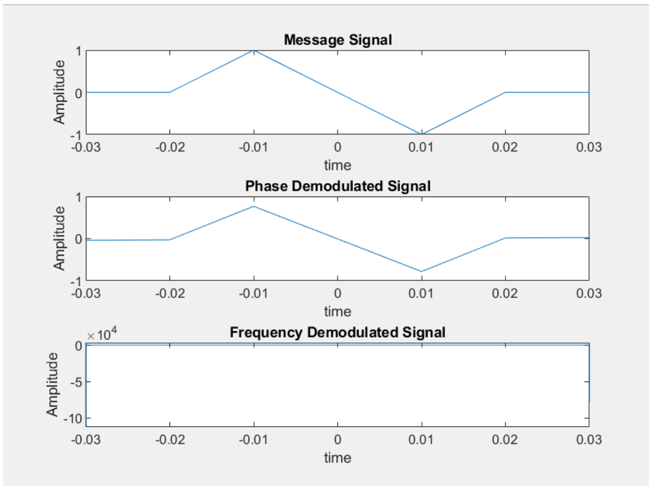
Demodulation: Now demodulate the produced FM and PM signals using a **crude discriminator**. Plot the original and demodulated message signals in a 3×1 plot.

Frequency spectrum: Plot the frequency spectra of the 3 signals, message signal, and FM and PM modulated signals in a 3×1 plot. Compare the bandwidth you observe in the FM plot with the values you get when you use Carson's formula.

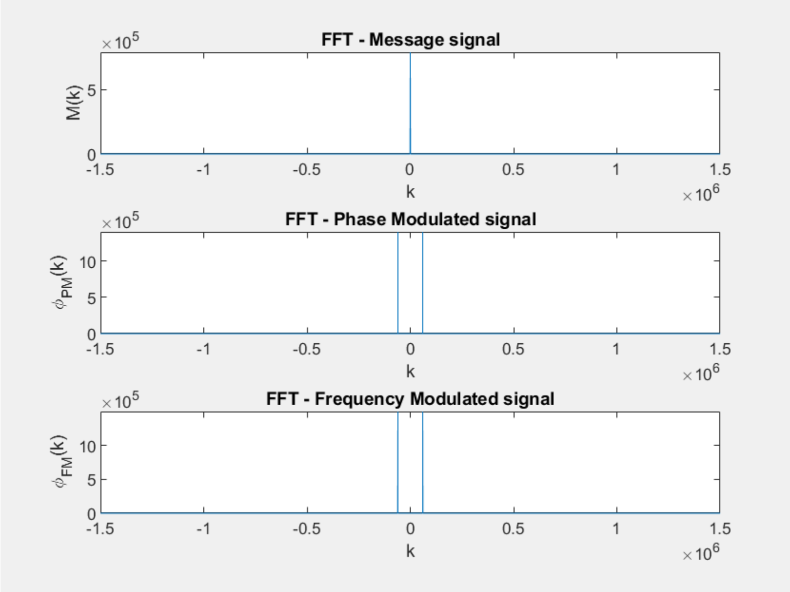
Plots for Q3:



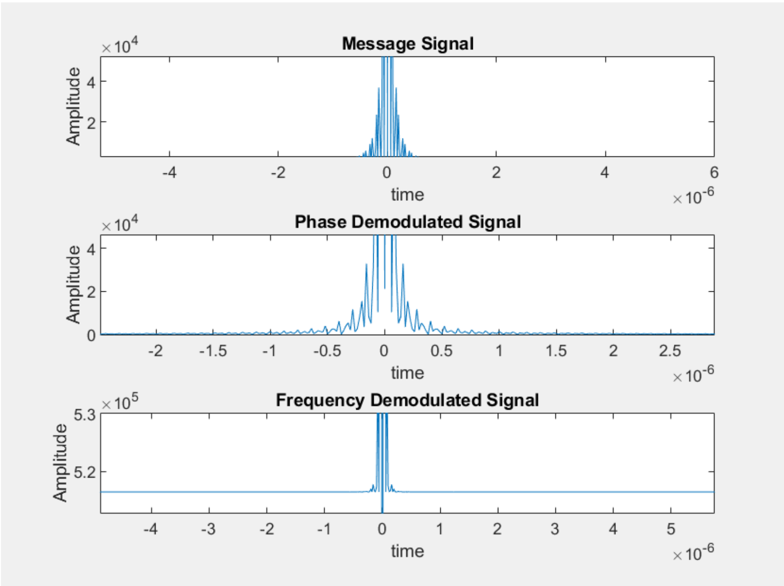
It is very difficult to observe the effects of FM and PM in this graph at such high values of Fc, but rest assured, the modulation is indeed happening as can be checked using lower frequencies.



Interestingly the effects of demodulation are not visible in the case of FM whereas they are loud and clear for PM demodulation. The reason will be visible in the next few plots where the FFT of the frequency demodulated signal will have an anomaly which makes render the graph as so.



Here, the differences in the plots is visible only when magnified where we see that the FM is spread relatively smoothly than PM around +-Fc which makes sense because the PM signal sees sudden phase shifts due to discontinuities in the derivative of the message signal as compared to FM signal where no such thing happens.



This is the plot of the demodulated signals along with that of the message signal. Here, if we observe the amplitude axis, we can see why PM demodulated signal looks similar to the message signal, but the FM demodulated signal sees a vertical shift in the amplitude and a compression of the base which distorts the output significantly!